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Procedia - Social and Behavioral Sciences 96 (2013) 1315 – 1321

Procedia
Social and Behavioral Sciences

13th COTA International Conference of Transportation Professionals (CICTP 2013)

Study on the Collision Avoidance Strategy at Unsignalized Intersection Based on PreScan Simulation

Zhizhou Wu^a, Jie Yang^{a,*}, Luoyi Huang^a^a*Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University, 4800 Cao'an Road, Shanghai, 201804, China*

Abstract

Considering the actual safety situation of unsignalized intersections and powerful support of high technology, the necessities for collision avoidance strategies at unsignalized intersections are presented in this study. A number of previous studies in this area are also summarized. With focusing on typical double-sided two-lane crossing unsignalized intersection, the through-through collision avoidance strategy with V2V communication is illustrated in detail. In this strategy, if a potential conflict is determined, the vehicle on the arterial road will send signal to the vehicle on the minor road, and the latter will make the way to the former once the warning signal is received. By simulating the scene in the Prescan software, the collision avoidance strategy is verified.

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Selection and peer-review under responsibility of Chinese Overseas Transportation Association (COTA).

Keywords: unsignalized intersection; inter-vehicle communication; collision avoidance strategy; simulation

1. Introduction

Unsignalized intersections have a significant impact on the operating efficiency and driving safety of the entire transportation system. The latest traffic statistics show that, there are about 40% traffic accidents occurring at the intersections, which include 28% at the unsignalized intersections and 12% at the signalized intersections respectively. The safety situation of unsignalized intersections is far more serious than that of signalized intersections (Xun Zhang, Wei Yang, et al. 2011). Domestic scholars have developed a lot of investigation and research about accident causes at the unsignalized intersection and found that the most influencing factor is the conflict problem. Therefore, how to eliminate the traffic conflicts and achieve the collision avoidance at the unsignalized intersections, has become an imminent traffic demand (Hao Chu, XiaoGuang Yang, et al. 2008).

* Corresponding author. Tel.: +86-188-173-09180;
E-mail address: yangjiewelcome@163.com

With the rapid development of wireless communication technology, the high-reliability communication between vehicles has become possible. Many scholars at home and abroad have explored the collision avoidance strategies at unsignalized intersections. Yuichi Morioka (2000) regarded that a collision would occur when the relative distance between the two vehicles was less than the minimum safe distance, so a warning signal was supposed to be sent out. Yiting Liu (2004) utilized the V2V communication simulator to simulate a variety of typical scenes and assessed the performance of collision avoidance system by analyzing the simulation results. Samer Ammoun (2010) built a risk assessment system involving four parameters: collision probability (CP), time to collision (TTC), the duration time of the collision (DTC) and the involved traffic flow (ITF). According to the calculation results, the degree of risk was determined and the collision avoidance strategy would be sent to the terminal at the same time. Huang L., Yang X. (2012) constructed a collision avoidance warning system based on the IEEE 802.11p prototype and the WSU communication equipments, the field test indicated that the system had a remarkable effect on the reduction of collision.

2. Collision Avoidance Strategy

The collision avoidance strategies are the key to avoid collision. They are divided into stand-alone strategies and coordinated strategies. The stand-alone strategies use the information of subject vehicle (SV) and sensors to estimate the likelihood of a collision and TTC value. When TTC is smaller than the given threshold, a warning signal will be triggered and sent out. The performance of the strategies is limited to the detection capacity of SV, leading to the obstacles cannot be detected effectively, so the effectiveness and suitability is poor in the real world. However, the coordinated strategies utilize the self-detecting system and communication module to collect the real-time state of its own and the neighbouring vehicles. What's more, the smooth communication link is conducive to detecting blind spot and area. The coordinated collision avoidance strategies were initiated by the General Motors research team which is in the name of Raja Sengupta in 2005, and achieved great effects in the field test. (Misener James A & Raja S., 2005)

When referred to the coordinated strategies, the vehicles are in the holographic traffic environment, they are able to see each other when covered into the communication coverage regardless of the obstacles. There has been a research focus on how to define a conflict and which strategy should be adopted to avoid it theoretically. Samer Ammoun (2009) compared the TTC with 2 s, supposing that the reaction time of the driver and vehicle is 1 s respectively, which did not consider the influence of GPS sensitivity or communication qualities. According to the principle of first-come, first-served, the vehicles which reach the conflict point earlier would have the priority to cross the intersection while the counterparts make the way. Anyway, the mentioned factors would produce certain deviation in the process of information transmission and the final effect, which would take more time to reach the driver. So the relevant deviation should be considered to ensure the accuracy and effectiveness.

In this paper, a collision avoidance strategy based on the V2V communication will be proposed. Take a simple double-sided two-lane unsignalized intersection for example, suppose that vehicle A and vehicle B are the head vehicles of the conflict flows from southern imports and eastern imports. Vehicle A runs from south to north and vehicle B moves from east to west. Their trajectories generate conflict at point C. Vehicle A has the priority to access the intersection. There are tall buildings and trees near the intersection, so the visual range is limited. At the same time, there are two assumptions needed to present, (1) the other motor vehicles on the lane, the non-motor vehicles, pedestrians and their behaviours are not taken into account; (2) the V2V communication is developed, vehicle A and vehicle B can perceive each other's speed, location, acceleration and related parameters with high accuracy and efficiency. The schematic diagram of the unsignalized intersection is shown in Figure 1.

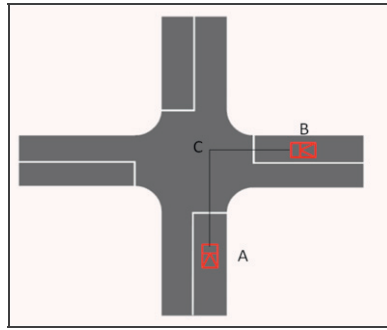


Fig. 1. The schematic diagram of the unsignalized intersection

When approaching the intersection, the controller of vehicle A begins to calculate the time difference to reach the potential conflict point according to the detecting information. The critical threshold of time difference is set to 3 s, considering the reaction time of people (1 s) and the vehicle (1 s) (Samer Ammoun, 2009), in combination with the time delay (1 s). When the time difference is smaller than 3 s, a conflict is considered to occur. Vehicle A is supposed to send warning signal to vehicle B. The control strategy is shown in Figure 2.

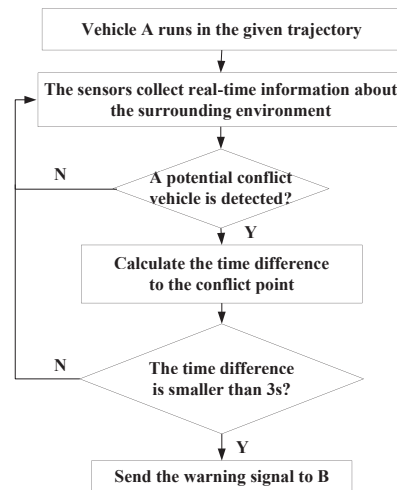


Fig. 2. The control strategy

3. Simulation and Verification

The PreScan simulation software is developed by the Netherlands Organisation for Applied Science Research (TNO). As an active safety experimental platform, PreScan simulation is able to build scenes based on the actual road environment and sensor model. The detecting information can be transferred into action by running the algorithm, so the intelligent vehicle system can be tested (<http://www.tass-safe.com/en/home>). By means of the PreScan, the scene of the vehicle on the minor road gives priority to the vehicle on the arterial road is simulated. When the two vehicles approach the intersection from perpendicular direction, once a potential collision is determined, the vehicle on the arterial road will send signals to the vehicle on the minor road, and the latter will decelerate after the signal is received, so the former can go through with the original speed.

3.1 Intersection scenario construction

According to the above presentation, build the scenario including the double-sided two-lane straight roads, two vehicles and some natural elements. The transmitting and receiving antenna are mounted on the roof of the two vehicles respectively, which can realize the target detection and signal transmission in a radiation range of 360° . The simulation scene is shown in Figure 3.

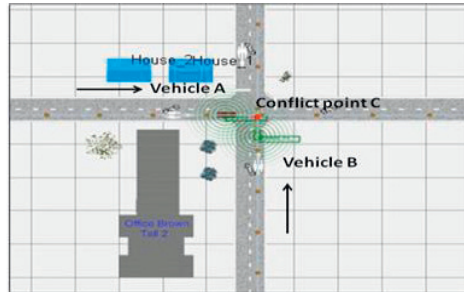


Fig. 3. The simulation scene

In order to simulate the collision scene, we set the same parameters for the two vehicles, that is, distance to the conflict point is 400 m, the total travelling distance is 800 m, the initial speed is 15 km/h, and then accelerate to 30 km/h. The relationship between travelling speed, distance, acceleration and time is shown in Figure 4.

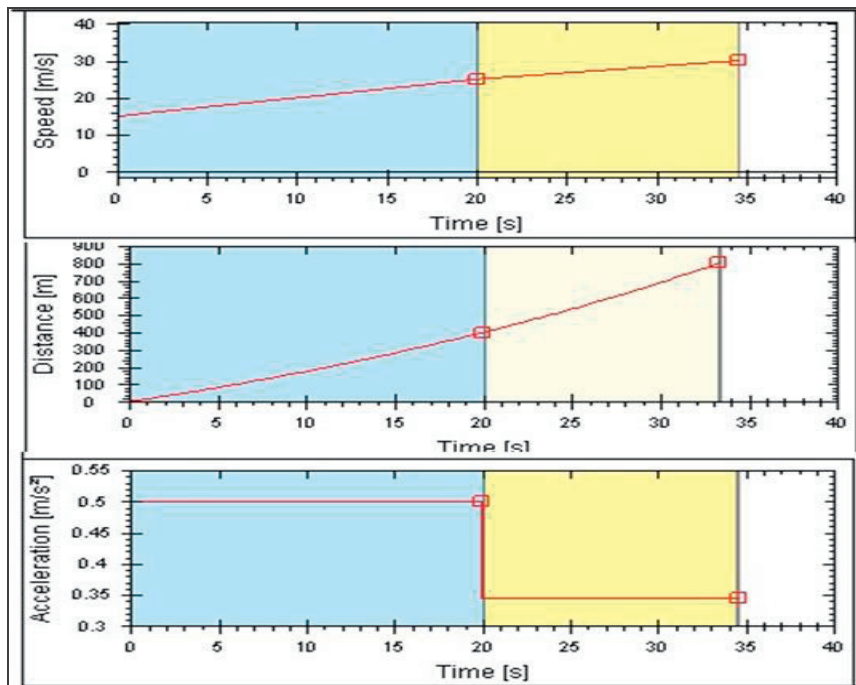


Fig. 4. Relationship between travelling speed, distance, acceleration and time

3.2 Configuration of vehicles and communication devices

Vehicle A and vehicle B use the vehicle model Mazda_RX8_1 and Fiat_Bravo_1 embedded in the system. The vehicle dynamics and physical parameters are shown in Table 1.

Table 1. Vehicle dynamics and physical parameters

Parameters	Mazda_RX8_1	Fiat_Bravo_1
Rotational friction coefficient	0.01	0.01
Drag coefficient	0.31	0.31
Maximum acceleration	0.3g	0.3g
Maximum deceleration	1g	1g
Mass	1480 kg	1330 kg
Area	1.97 m ²	2.3 m ²
Dimensions	4425*1860*1314 cm	4331*2060*1574 cm

Table 1 shows that the vehicle simulation models have relatively high fidelity when referred to the geometric shape. What's more, the vehicle dynamics parameters are precise enough to match parameters in reality. Take the communication range and transmission reliability of sensors into consideration, choose the transmitter Antenna_Tx_1 and the receiver Antenna_Rx_1 as inter-communication medium. The channel value is set to 1 to achieve smooth information exchange. The radiation range of the transmitter is set to -1 to indicate infinite coverage. The maximum target number that can be detected by receiver is 1. The detailed parameter setting interfaces are demonstrated in Figure 5.

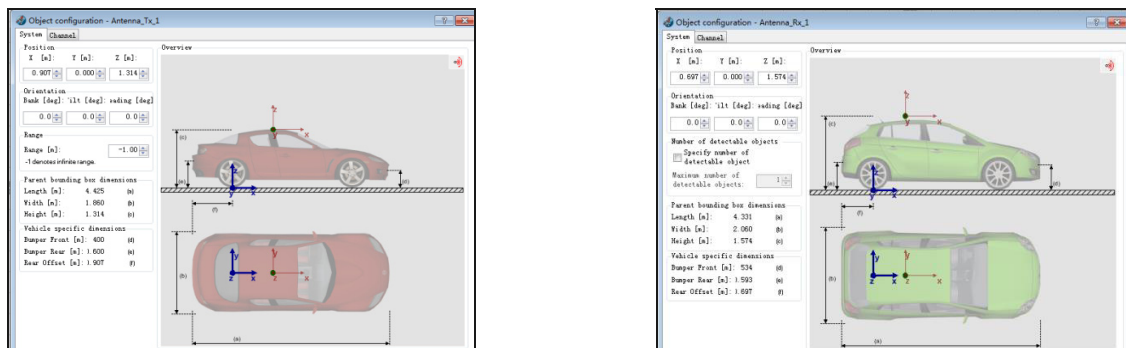


Fig. 5. The parameter setting of antenna

3.3 Simulation and results

Define the vehicle A as object vehicle and vehicle B as subject vehicle. The subject vehicle applies to the two-dimension vehicle dynamics model and Pathfollower driving model. The channel of transmitting antenna in vehicle A is set to constant value, so the corresponding channel of receiving antenna in vehicle B will receive the signal and transfer it into the variance of target speed, that is 10 m/s. The connection diagram of state information of vehicle B and Pathfollower in Matlab/Simulink module is shown in Figure 6.

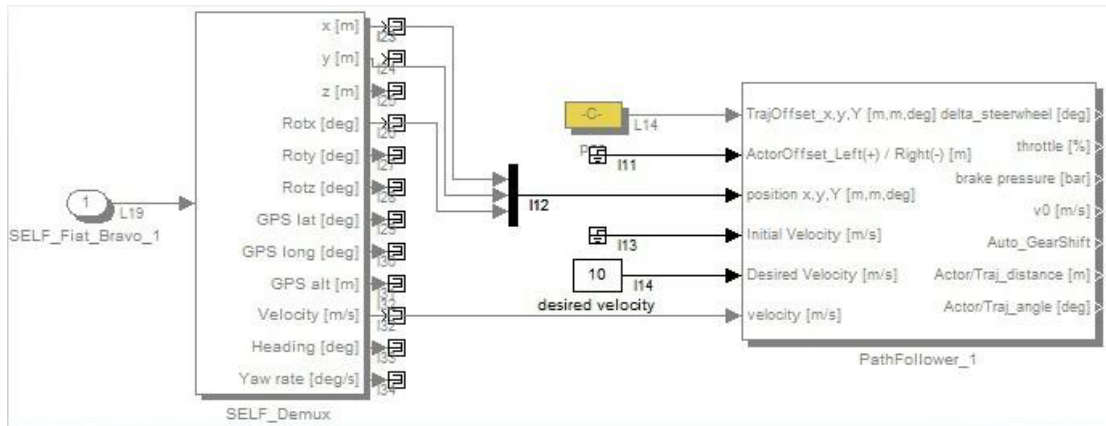


Fig. 6. The connection diagram between vehicle B and Pathfollower

In the graphic user interface of PreScan, implement the parse, build order and run the PreScan/Matlab programme, the control strategy will be activated and the simulation will be achieved.

The results show that, vehicle B begins to decelerate when the time is 17.14 s and the travelling distance is 300 m. When the time is 23.81 s and the travelling distance is 400 m, which is exactly the conflict point position, the speed of vehicle B drops to 10 m/s. However, at this time, the travelling distance of vehicle A is 501.9 m, which shows that vehicle A has passed the conflict point, so the collision between vehicle A and vehicle B is avoided successfully. The driving state of vehicle B is shown in Figure 7.

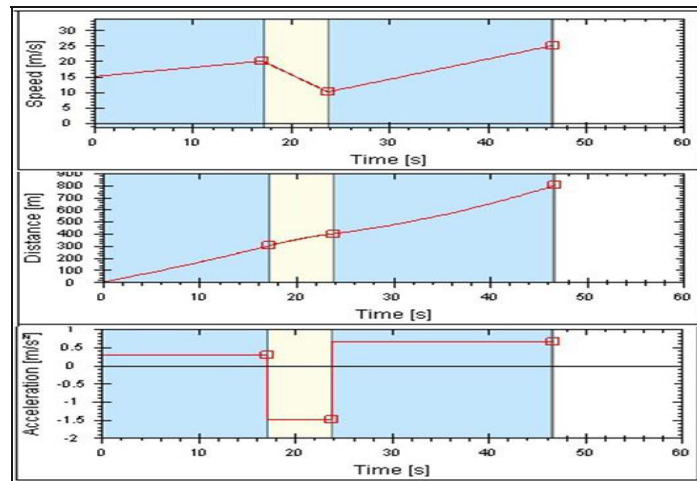


Fig. 7. The driving state of vehicle B

4. Conclusion

Firstly, the necessity for collision avoidance strategy is put forward with the serious safety situation of unsignalized intersections and the powerful support of advanced technology, and some previous studies are given out. Secondly, stand-alone strategies and coordinated strategies are introduced. Take the simple through-through

collision case as an example, the collision avoidance strategy of vehicles on the arterial road and minor road under V2V communication is illustrated in detail. Thirdly, use the PreScan software to build a collision avoidance scene at unsignalized intersection. Some basic parameters are set and the strategy is carried out. The simulation results show that the vehicle on the minor road begins to decelerate 100 m away from the conflict point after receiving the warning message and the collision is avoided.

In the paper, for the purpose of easy implementation, the trajectories of the two vehicles and collision type have been defined in advance and the impact of other non-motor vehicles and pedestrians is ignored, so combining with actual running trajectories of vehicles such as turning left, going straight and turning right, giving out the collision avoidance strategy dynamically will be the research direction in future.

Acknowledgements

The research was supported by the National High-tech R&D Program (863 Program,1600243001)

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